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ABSTRACT

This paper reports on a project to enrich high school algebra and geometry programs through the use of manipulatives. The evaluation design utilized qualitative and quantitative methodology to determine the effectiveness and impact of training with manipulatives on 40 high school teachers. The final evaluation was based on: (1) review of the program proposal; (2) participation in the planning process for the workshops with the project staff; (3) observation of the methodology of the trainers and provisions for participant involvement in each of the workshop sessions; (4) group discussion of classroom implementation strategies; (5) observation of the use of manipulatives in the participants' classrooms; and (6) review of participants' self-reports of student utilization and response to the manipulatives. The project was successful in addressing the stated objectives of the proposal through the techniques of well organized workshop training sessions, follow-up reporting and evaluation, and extended local training. The manipulatives are being used extensively, and student attitudes, participation, and performance have been enhanced. (MKR)

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Evaluation of the Effectiveness and Implementation of a Math Manipulatives Project

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Evaluation of the Effectiveness and Implementation of a
Math Manipulatives Project

In March, 1989, the National Council of Teachers of Mathematics (NCTM) released its *Curriculum and Evaluation Standards for School Mathematics.* These standards were the result of three years of planning, writing, and consensus-building to reflect solutions to national concerns about students' mathematical performance.The NCTM Standards propose the development of enhanced mathematical power for all students by providing students with experiences to explore and reason, solve nonroutine problems, and develop personal self-confidence. Two assumptions about teaching and learning are central to this proposal: teachers are key figures in changing the ways in which mathematics is taught and learned in schools, and these changes require that teachers have long-term support and adequate resources. Specifically, designing effective experiences for students requires teachers with proficiency in using and helping students use, technology and other tools to pursue mathematical investigations and the ability to guide students in individual, small-group, and whole-class work.

The use of mathematical tools such as manipulatives has gained research support in the last two decades (Post, 1980; Raphael & Wahlstrom, 1989; Suydam & Higgins, 1977). Sowell (1989) concluded that mathematics achievement is increased by the long term use of manipulatives and that student attitudes toward mathematics are improved when they are instructed with manipulatives. Significant factors in mathematical achievement are the inclusion of manipulatives and the expertise of the teachers using the manipulatives.

Project Design

Based on the NCTM assumptions, research findings, and state and national efforts to improve mathematics education, Talladega College, in conjunction with high schools within a forty mile radius, developed a project to enrich algebra and geometry programs through the utilization of manipulatives. Through participation in a week-long intensive training workshop and year-long followup activities, it was proposed that participants would a) enhance their teaching skills with the technological devices,

b) develop techniques for classroom implementation, and c) assess changes in students' achievement and attitudes.

Instructional Techniques

The workshop manual developed for the participants and the training sessions provided each participant with knowledge of the manipulatives approach to teaching mathematics. They gained knowledge from the printed materials and by observation of the methodologies utilized by the trainers. They also developed their own skills by formulating and presenting lessons as a culminating activity of the workshop. The participants received the kits, were trained, and had the opportunity to practice with the components during the workshop sessions.

Followup activities

The participants have provided inservice training for other teachers at the local level by conducting formal training sessions for 25 teachers, conducting informal training sessions on Saturday mornings, and by co-teaching situations in which implementation was demonstrated on a daily basis.

All participants returned to Talladega for a 3-hour session in which specific strategies and problem areas were identified and discussed. The project staff provided feedback and suggestions for solutions for the identified problems. In addition, each teacher was observed by a project staff member, and practices were reviewed and discussed on-site.

Assessment

Dual assessment techniques were utilized : a) the effectiveness of the project instruction based on perceptions of the participants and observations by the project staff in an on-site immediate mode, and b) the effectiveness of the instruction based on degree and success of implementation and impact on students throughout the school year. The assessment component incorporated NCTM's evaluation assumptions that the overall intent is to improve instruction and that teachers should be an integral part of that process. The standards emphasize that teachers should be encouraged and supported to engage in self-analysis and to work with colleagues in improving their teaching (NCTM, 1989). The participants utilized quantitative assessment instruments at the end of each session and completed a qualitative

instrument to assist them in assessing impact on their teaching and their students' learning at the followup session.

Teachers were asked to identify differences in their lesson plans and purposes with manipulatives and differences in their students' attitudes, participation, and performance. These differences were discussed and analyzed at the time of the local site visits during the second semester of implementation. The process of identifying the differences was incorporated to cause the teachers to reflect on the impact of the manipulatives.

Methodology

Study Design

The evaluation design utilized qualitative and quantitative methodology to determine the effectiveness and impact of the training with manipulatives. The final evaluation is based on a) review of the Eisenhower Proposal, b) participation in the planning process for the workshops with the project staff, c) observation of the methodology of the trainers and provisions for participant involvement in each of the workshop sessions, d) group discussion of classroom implementation strategies, e) observation of utilization of manipulatives in the participants' classrooms, and f) review of participants' self reports of student utilization and response to the manipulatives. Data collected from these resources were used to "assess the degree to which teachers are implementing the ideas and materials from the ... workshops" (*Project Narrative*, 1993, p. 14).

Instruments

The effectiveness of the instruction of the workshops was measured by the *Evaluation of Eisenhower Workshop* qualitative checklist (Appendix A) administered to the participants at the end of the week of each workshop session. Participants' perceptions of the usefulness of the provided manipulatives was assessed at the end of each session by the *Participant Rating of Usefulness of Mathematics Manipulatives* (Appendix B).

The *Evaluation of Eisenhower Workshop* qualitative checklist, created by one of the Project Directors, consisted of four open-ended questions which assessed a) quality of instruction, b) most valuable workshop components, c) least valuable

workshop components, and d) additional suggestions for improvement or future workshop topics.

The *Participant Rating of Usefulness of Mathematics Manipulatives*, also created by one of the Project Directors, consisted of 23 items on a rating scale of 1-5 (5 = most useful and 1 = least useful) and 3 open-ended questions assessing most useful material, least useful material, and recommendations for additional resources.

The degree of implementation and student response to the manipulatives were reported on the *Math Manipulative Observation* (Appendix C) and *Math Manipulatives Workshop Followup* (Appendix D). Evidence of utilization and preliminary impact of the manipulatives as reflected in students' attitudes, class engagement, interaction with content, and academic performance was determined through the *Math Manipulatives Observation*, used by the project staff during on-site observations, and the *Math Manipulatives Workshop Followup*, a self-report by the participants.

The *Math Manipulatives Observation* instrument was developed by the evaluator and designed to focus responses by the five observers during on-site observations. The evaluator provided training for the observers in the use of the instrument to enhance reliability in the recording of data. The observers recorded utilization by course and manipulative, student participation and attitudes toward the manipulatives, and interaction with the content.

The *Math Manipulatives Workshop Followup* was designed to report courses in which manipulatives had been incorporated; differences in lesson plans; differences in students' attitudes, participation, and achievement; and techniques utilized to train other teachers.

Sample

A total of 40 teachers representing 26 schools participated in the workshop and the evaluation processes. One of the original participants was reassigned as a counselor for the academic year, and one participant was not teaching courses with manipulatives during the observation period. Therefore, 38 teachers were observed, with a range of experience from 1 - 42 years, and a mean of 17.5 years. Classes observed included: Math 7, Math 8, General Math, Pre-Algebra, Consumer Math, Technical Math, Algebra I, Algebra II, Geometry, Trigonometry, and Pre-Calculus.

Procedures

These data were gathered by self-report by the participants and on-site observations by the project directors, the workshop presenters, and the outside evaluator.

Treatment of the Data

Analysis of the data was conducted by the project external evaluator. The responses to the *Evaluation of Eisenhower Workshop* qualitative checklist were reviewed and coded. Categories of responses were identified which allowed summing of the responses according to teaching characteristics, strategies employed, and specific manipulatives. Frequencies, mean ratings, and rank order were calculated for the 23 items of the *Participant Rating of Usefulness of Mathematics Manipulatives* .

Data from the *Math Manipulatives Observation* instrument included calculating frequencies for utilization of manipulatives and coding and identifying categories for the open-ended observations. The self-report *Math Manipulatives Workshop Followup* instrument yielded qualitative data which were coded, categorized, and summarized.

Results and Discussion

Evaluation of Eisenhower Workshop

Analysis of the codes and categories identified by the evaluator revealed assessment of the quality of instruction in the excellent (73%) to very good (18%) range. The participants were enthusiastic in their descriptions of the presenters as "knowledgeable," "caring" and "personable," and as being "well organized" and "on task." The responses to "the most valuable part" of the workshop included specific manipulatives as well strategies employed in the training. The TI-81 graphing calculator was identified by 73% of the participants and 40% specified "comparing ideas" with other teachers. The most frequently cited "least useful" part was "none," indicating that all parts were useful. Seven participants identified the dice as least useful. Additional comments included best workshop attended and suggestions for yearly followups and manipulatives for hands-on equations.

Participant Rating of Usefulness of Mathematics Manipulatives

As shown in Table 1, the means of the ratings range from 3.05 to 4.90,

indicating that all the manipulatives were rated in the useful category, with 19 of the 23 items rated as 4 or better. Review of the manipulatives in rank order reveals that the calculators and geoboards were identified as the most useful items.

The open-ended responses were consistent with the numerical ratings: the calculators were identified as the most useful and the geoboards were the second most cited manipulative. The dice and the spinners were identified as least useful. It is recognized that the participants' ratings of the usefulness are determined by the subject matter and student response; therefore, the homogeneity of responses indicates strong support for the inclusion of calculators and geoboards in the mathematics classroom.

Math Manipulatives Observation

Attitudes. Observers concluded that students enjoyed using the manipulatives as expressed through their verbal and nonverbal behaviors. They were involved with the manipulatives and the tasks associated with them. Students exhibited confidence, eagerness, a desire for other experiences, and an inquisitive approach in their use of the manipulatives.

Participation. The "on task" involvement was very high, 100% in most classes. Observers noted an enhanced willingness to respond to questions and several students extended discovery beyond the assignment.

Interaction. Observers noted that the students seemed to comprehend tasks with accuracy, employed discovery and problem solving strategies, were anxious to share their discoveries and solutions, engaged in lively student/student interaction related to the content, and exhibited an excitement about learning.

Math Manipulatives Workshop Followup

Planning. Teachers indicated that more time was needed for planning and more class time was needed when manipulatives are used, but student participation is enhanced. The manipulatives supplement and reinforce established concepts and allow them to utilize discovery groups to a greater extent.

Attitudes. The teachers reported that the students enjoy and are more interested in assignments (and even express excitement) when manipulatives are used. They are more active in class, develop self-confidence in their math skills, and

are willing to experiment.

Participation. Enhanced participation and a desire to participate were reported by the teachers. Some teachers noted more student cooperation and enhanced student/teacher interaction. Manipulatives were the catalyst for participation by some who normally are nonparticipants.

Performance. Most teachers noted that the intervention time was too short and no pretest data were available to detect differences in standardized test scores, but other improvements were noted. Improvement on local tests was noted by 46% of the teachers, and others noted that the students exhibited understanding of the concepts to a greater degree. Two teachers noted that below average students' scores improved, and other teachers noted improvements in Algebra and General Math scores.

Inservice training. All teachers have been involved in some type of activity to train other teachers in their schools or systems. They have conducted formal training sessions for 12-25 teachers, conducted informal training sessions after school and on Saturday mornings for one to nine teachers, shared ideas including developing lesson plans with one to five teachers, and co-taught in which implementation was demonstrated on a daily basis.

In conclusion, the project was successful in addressing the stated objectives of the proposal through the techniques of well organized workshop training sessions, followup reporting and evaluation, and extended local training. The manipulatives are being utilized extensively, and student attitudes, participation, and performance have been enhanced.

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TABLE 1 USEFULNESS RANKINGS

	A	B	C	D	E	F	G
1	MANIPULATIVE	RATING	RATING	RATING	RATING	RATING	MEAN
2	NAME	5	4	3	2	1	RATING
3		FREQUENCY	FREQUENCY	FREQUENCY	FREQUENCY	FREQUENCY	X
4	OVERHEAD TI-34 CALCULATOR	37	2	1	0	0	4.90
5	TI-34 CALCULATORS	35	3	2	0	0	4.83
6	TI-81 GRAPHING CALCULATOR	36	1	0	1	0	4.65
7	WOODEN GEOBOARDS	27	12	1	0	0	4.65
8	OHP GEOBOARD	25	14	1	0	0	4.60
9	OHP TI-81 GRAPHING CALCULATOR	34	3	0	0	1	4.58
10	RUBBER BANDS	25	13	2	0	0	4.58
11	OVERHEAD TRIMAN COMPASS	26	9	4	1	0	4.50
12	SAGE KIT GEOMETRIC MODELS	25	10	4	1	0	4.47
13	TRIMAN CLASSMATE COMPASSES	25	10	4	1	0	4.47
14	OVERHEAD ALGEBRA TILES	22	12	6	0	0	4.40
15	ALGEBRA TILES	22	11	7	0	0	4.38
16	OVERHEAD ATTRIBUTE BLOCKS	20	14	6	0	0	4.35
17	TRIMAN CIRCLE PROTRACTORS	23	10	4	2	0	4.28
18	COLOR CUBES	16	19	5	0	0	4.28
19	OVERHEAD PATTERN BLOCKS	18	15	6	1	0	4.25
20	PATTERN BLOCKS	18	15	6	1	0	4.25
21	TRANSPARENT CIRCULAR COUNTERS	18	10	10	1	1	4.08
22	OVERHEAD COUNTERS	20	9	7	1	1	4.00
23	DICE	13	11	9	7	0	3.75
24	OVERHEAD FRACTION BARS	14	12	7	2	3	3.65
25	OVERHEAD SPINNERS	10	14	10	5	0	3.65
26	POLYHEDRA DICE	5	9	13	10	2	3.05

APPENDIX A

EVALUATION OF EISENHOWER WORKSHOP CONDUCTED BY TALLADEGA COLLEGE DURING SUMMER 1993

Please comment on the quality of instruction provided by the project staff.

Identify the most valuable parts of the workshop.

Identify the least valuable parts of the workshop.

Please make any additional comments on ways to improve future workshops and/or give additional topics to be covered.

APPENDIX B

PARTICIPANT RATING OF USEFULNESS OF MATHEMATICS MANIPULATIVES

Please rate on a scale from 1-5, with 1 being least useful and 5 being most useful, your evaluation of each component of the Mathematics Manipulatives Kit.

___ 1 Set Dice (6 Pairs in 3 Colors)
___ 5 Sets/6 Polyhedra Dice
___ 4 Sets/4 Overhead Spinners
___ 1 Set/250 Pattern Blocks
___ 1 Set/49 Overhead Pattern Blocks
___ 1 Set/200 Transparent Circular Counters
___ 1 Set/250 Overhead Counters
___ 1 Set/100 Color Cubes
___ 1 Set/36 Overhead Attribute Blocks
___ 15 Wooden Geoboards
___ 1 Package Rubber Bands in 3 Colors
___ 1 Overhead Geoboards
___ 1 Set Overhead Fraction Bars
___ 15 Sets/32 Algebra Tiles
___ 1 Set/70 Overhead Algebra Tiles
___ 15 Triman Circle Protractors
___ 15 Triman Classmate Compasses
___ 1 Overhead Triman Compass
___ 1 Sage Kit Transparent Geometric Models
___ 15 Calculators TI-34
___ 1 Overhead Calculator for TI-34
___ 5 Calculators TI-81 (graphing)
___ 1 Overhead Calculator for TI-81 (graphing)

1. Which of the materials did you find to be most useful?
2. Which of the materials did you find to be least useful?
3. What additional resources would you recommend for teachers of grades 7-12 mathematics?

PLEASE USE THE SPACE BELOW FOR THESE AND/OR ADDITIONAL COMMENTS.

Appendix C

MATH MANIPULATIVES OBSERVATION

NAME_____SCHOOL_____

SYSTEM_____COURSE_____

DATE _____TIME_____

PURPOSE OF LESSON _____

_____

MANIPULATIVES UTILIZED_____

_____

HOW MANIPULATIVES WERE UTILIZED (DEMONSTRATION, LARGE GROUP, SMALL GROUP, INDIVIDUAL HANDS-ON)_____

_____

_____

STUDENTS' ATTITUDES TOWARD USE OF MANIPULATIVES :

_____

_____

_____

_____

STUDENTS' CLASS PARTICIPATION WHEN MANIPULATIVES ARE UTILIZED:

_____

_____

_____

INTERACTION OF LEARNERS WITH CONTENT DUE TO USE OF MANIPULATIVES _____

_____

REVIEWER_____

Appendix D

MATH MANIPULATIVES WORKSHOP FOLLOWUP

NAME_____#YRS. TEACHING MATH_____

COURSES IN WHICH MANIPULATIVES/TECHNIQUES FROM SUMMER WORKSHOP HAVE BEEN INCORPORATED:

_____ _____

_____ _____

HOW ARE LESSON PLANS/PURPOSES DIFFERENT WITH MANIPULATIVES?_____

_____

_____

DESCRIBE ANY DIFFERENCES YOU HAVE OBSERVED IN **STUDENTS' ATTITUDES** WHEN MANIPULATIVES ARE UTILIZED:_____

_____

DESCRIBE ANY DIFFERENCES YOU HAVE OBSERVED IN **STUDENTS' CLASS PARTICIPATION** WHEN MANIPULATIVES ARE UTILIZED:

_____

_____

DESCRIBE ANY DIFFERENCES YOU HAVE OBSERVED IN **STUDENTS' PERFORMANCE ON YOUR TESTS OR STANDARDIZED TESTS** WHEN MANIPULATIVES ARE UTILIZED:_____

_____

HAVE YOU PROVIDED ANY TRAINING OF OTHER TEACHERS IN YOUR SCHOOL OR SYSTEM? _____ IF YES, DESCRIBE NUMBER OF TEACHERS AND NATURE OF TRAINING. _____

_____

_____IF NO, INDICATE WHEN AND HOW IT IS PLANNED:_____